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The effect of use of concept maps on problem solving performance and attitude in Mechanical engineering course

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Abstract

The aim of this study is to investigate the effect of concept mapping strategy on the performance of the students in problem solving. The study was done on a sample of 84 third year undergraduate mechanical engineering students. The subject of the study was Internal combustion engines at a college of engineering of the University of Mumbai. The study used a pre-test and post-test quasi-experimental design method on a control group and an experimental group. Each group consisted of 42 students. The study was conducted over a six weeks period. The experimental group was taught the topic of Introduction to internal combustion engines with concept maps as a teaching-learning method. The control group was taught the same topic without the use of concept maps. The experimental group revealed two results. Firstly, adopting concept mapping strategy can significantly improve students' performance in problem solving compared to using traditional teaching methods. There were significant differences favoring the experimental group for the well structured problem solving performance while there were no significant differences on ill structured problem solving performance. Secondly, most of the students were positive about using concept mapping strategy in an internal combustion engine course. They indicated that concept maps can help them to understand, identify the key concepts, and connect the various concepts.

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1. Introduction

Engineering is an area of human activity which requires the application of skills based on the knowledge of mathematics, logic, science, technology and economics. Teaching of engineering subjects must contribute to the development of knowledge of skills, problem solving capacity and thinking abilities. One of the major goals of engineering education is to enable students to use their domain knowledge in problem solving (Heller et. al 1992, McDermott et.al 1991, Reif et.al 1976, Reif et.al 1981). Problem solving is considered as one of the most important learning activity in engineering education. Very few teaching-learning strategies are available for designing problem solving Instructions (Johanson et. al 1998).

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Many engineering educators are of the opinion that problem solving is an activity which emphasis on meaningful learning (Glenn W. Ellies et.al 2004). However, most taxonomies of learning do not consider it as a major learning outcome. In order to cope up with the complexity of knowledge in problem solving, there is a need to organize, store and apply knowledge to real life situations (Chao boon Teo et.al 2006).

Concept maps are considered to be potentially powerful problem-solving tools (Jonassen 2004, Stoyanov 2001). From this aspect, concept maps become a valuable tool for the development of problem solving abilities. Problem solving is a complex activity which involves a variety of components that include concepts, rules and principles. However, it also involves structural knowledge, ampliative skills and metacognition skills (Stoyanov 2001).

Jonassen proposed taxonomy of problems and ranking problems types from well to ill structured problems. These taxonomy categories include "puzzles, algorithms, story, rule using, troubleshooting, decision making, diagnostic solution, strategic performance, case analysis, designs and dilemma".

This study distinguishes between well structured problems and ill structured problems. A well structured problem requires applications of a limited number of rules and principles within well defined parameters (Stoyanov et.al 2006).Well structured problems provide convergent solutions. Ill structured problem proposes multiple solutions, multiple paths and contain uncertainty about concepts, rules, and principles which are necessary for solutions (Stoyanov et.al 2006).

2. Overview of concept maps

Concept map are not a new phenomenon in engineering education. Concept maps are nowadays used to enhance "meaningful learning". According to Ausubel (1968), "the most important single factor influencing learning is what the learner already knows" (Novak & Gowin 1985).

Concept maps are diagrams that present the mental connections and association of structures of student knowledge (Angelo and Cross 1993). In its simplest form, a concept map connects only two concepts by a linking word (Novak and Gowin 1984). A concept map consists of nodes (which represent concepts), and links (which show relationship among concepts). These nodes and links are arranged in a structure (hierarchical, cyclic or hybrid) to represent all the key concepts (Novak & Gowin 1985).

A concept map can be used as a graphical tool to activate prior knowledge, to support problem solving, to enhance conceptual understanding and to organise and revise knowledge (Zwaal & Otting 2012). Concept mapping has been successfully used as assessment technique (Constantinou 2004; Fernandes, Kommers & Asensio 2004; Novak 1998; Weber 2004), as a learning tool to help the students to organize their structured and declarative knowledge (Gulmans 2004; Jonassen, 2004, Lumer & Hesse 2004; Lumer & Ohly, 2004; Novak 1998) and as a advanced organizer (Novak & Gowin 1984; Novak 1998). There is very little research on the use of concept mapping for problem solving technique (Jonassen 2004; Stoyanov 2001).

Jonassen (2004) defines concept map as an instrument for showing the semantic organization of problems by students. Concept mapping is defined as knowledge representation tool (Gulmans 2004; Huai & Kommers 2004; Jonassen, Hong, Harvey & Peters 1998; Kenedy & McNaught 1998). As a knowledge representation tool for problem solving, it has some features to externalize the mental model of students (Stoyanov 2001). One experimental study (Braselton & Decker 1994) with sixth-grade mathematics students found concept mapping tools to be advantageous in the improvement of students' problem-solving skills.

Although concept mapping widely used in various disciplines, concept mapping has not been tested in problem solving in mechanical engineering.

3. Objectives of the study

In the present study, concept mapping technique is used as a supportive method to enhance problem solving abilities in the teaching of topic introduction to the internal combustion engine (IICE) in the classroom.

The research questions investigated in this study were as follows:-

i) Is there any effect of concept mapping strategy on the performance of students' in problem solving in IICE?

ii) What are students' perceptions towards concept mapping as an instructional strategy?

The scope of this study is limited to the effect of concept maps on the learning of concepts related to the introduction to the internal combustion engine. Only students' and expert generated map concepts maps were used in this study.

4. Methodology

4.1 Participants

Participants were 84 students enrolled in a third year mechanical engineering undergraduate course in the course of internal combustion engine at Mumbai University, India. The topic taught was introduction to the internal combustion engine (IICE). This study was conducted over a period of six lecture module on the topic of IICE. Participants were randomly divided into two groups: experimental group and control group. The experimental group was taught the topic of IICE with the use of concept map while control group was taught the same topic with normal traditional teaching method. In order to avoid the confounding effect of the experiment, the same teacher taught the topic of IICE with same books. The experimental group received training about the construction of concept maps in the first two hour of instruction. No student was having previous experience of use of concept mapping. The data analysed for this research were taken from 42 students participating in the experiment and 42 students participating in the control group. The independent variable was the use of concept maps and dependant variable was score in the problem solving test of IICE. After the end of the instructions of experimental group, students were asked to draw the concept maps. Then these students generated concept maps are evaluated with the use of expert map. The expert map was developed by the teacher.

4.2 Instruments

The data collected at the end of instructions of the topic of IICE consisted of the results of problem solving performance test. This problem solving performance test consisted of two parts; namely well structured problem solving test (WSPST) and ill structured problem solving test (ISPST). The total score consists of the sum of WSPST and ISPST scores and has a maximum possible score of 70. Later, an anonymous survey was administered in the experimental group about the perception of the concept maps. WSPST contains questions related with the application of concepts and rules within well defined parameters. It has 7 multiple choice questions and the K-R 20 reliability coefficient of the instruments was 0.76. ISPST contains questions which leads to multiple solutions, and contains uncertainty of concepts. ISPST has 7 short answer questions and has maximum score of 35.

A satisfaction questionnaire was designed by the teacher to know the attitude of students towards concept mapping strategy. The questionnaire has 6 items and was rated on a five point Likert scale from 1(strongly disagree) to 5 (strongly agree). The Cronbach alpha coefficient of this questionnaire was 0.83.

4.3 Procedure

The study was conducted in the sixth semester of mechanical engineering students. The experimental group (use of concept maps) and control group (traditional teaching) were pre-tested for their knowledge of thermal science. The study was conducted for the period of six weeks. The class met three times per week for sixty minutes each. The topic of IICE contains concepts of engines, types of engines, spark ignition (SI) engine, compression ignition (CI) engine, two stroke engine, four stroke engine, scavenging, cooling system, lubrication system, ignition system, thermal efficiency, brake power, indicated power, Otto cycle, Diesel cycle, application of engines, valve timing diagram, specific fuel consumption, brake thermal efficiency, indicated thermal efficiency and mechanical efficiency. The same teacher taught the topic to both the groups. The experimental group got training of two hours for creation of concept maps in addition to the normal six week teaching module. The teacher provided the list of concepts to the students of experiment group. The students in the experimental group submitted the concept maps constructed by them to the teacher. Students were given detailed feedback about the concept maps. The students in the control group completed their learning in six weeks time. At the end of treatment period, both experimental group and control group took problem solving performance test consisting of WSPST and ISPST. A questionnaire was also administered to know the perceptions of the students towards concept mapping.

5. Results

5.1 Pre test

The mean score of the pretest for the experimental group was found to be 24.07, while the score of control group was found to be 22.45 out of a maximum possible score of 40.

A t-test for independent samples indicates that there were no significant differences between the two groups ($t = 1.22$, $p > 0.05$). Table 1 shows the means and standard deviation of both the groups. Table 1 shows that there is no significant difference between experimental and control group ($t = 1.22$, $p > 0.05$).

Table1 Means and standard deviations of experimental group and control group (pre-test)

	Experimental group			Control group				
Measures	N	Mean	SD	N	Mean	SD	t	p
Pre-test	42	24.07	6.94	42	22.45	5.07	1.22	0.22

5.2 Post – test

Because there were no significant differences in the pre-test, it was assumed that the two groups that we started out with are statistically equivalent. Table 2 shows the means and standard deviations of the post test results for the experimental group and the control group. The total post test score consisted of the sum of scores of WSPST and ISPST. A t-test for independent samples was carried out to test whether the experimental and control group differed significantly on post test performance in problem solving in IICE. A significant difference was found between experimental and control group ($t = 2.64$, $p < 0.05$). The mean score for the experimental group (adopting the concept mapping strategy) was 23.45, while the mean score for the control group (using the traditional teaching method) was 19.71

Table 2 shows that the mean of the post test score in problem solving in the experimental group is higher than that in the control group ($t = 2.64$, $p < 0.05$). The results showed that there were significant differences between the dependent variables in the teaching methods used.

Table 2 Means and standard deviations of experimental group and control group (post-test)

	Experimental group			Control group				
Measures	N	Mean	SD	N	Mean	SD	t	p
Post-test	42	23.45	5.99	42	19.71	6.91	2.64	0.010

In addition, a t-test for independent samples was carried out to test whether the scores of experimental and control groups differ significantly at different levels of cognitive structure (well structured and ill structured problem solving skills).

Table 3 shows that the mean of the post test score in well structured problem solving (WSPST) in the experimental group is higher than that in the control group ($t = 2.49$, $p < 0.05$). The results showed that there were significant differences between the dependent variables in the two teaching methods used.

Table 3 shows that there was a no significant difference ($t = 0.561$, $p > 0.05$) in the ill structured problem solving test scores between the two groups. The results of ISPST showed that there were no significant differences between the dependent variables in the teaching methods used.

Table 3 Means and standard deviations of experimental group and control group (WSPST and ISPST)

	Experimental group			Control group				
Measures	N	Mean	SD	N	Mean	SD	t	p
WSPST	42	13.45	5.57	42	10.35	5.77	2.49	0.014
ISPST	42	10.00	1.63	42	9.80	1.46	0.561	0.576.

The result obtained seems to suggest that the concept mapping strategy improved the students' performance in problem solving than the traditional teaching method (without the use of concept maps). However, student's performance in well structured problem solving improved but there was no difference in ill structured problem solving performance.

5.3 Student's perceptions towards concept mapping

To evaluate the students' attitude towards concept mapping and the use of this tool in problem solving of topic of introduction to internal combustion engines, questionnaires were administered to the students. The students were questioned on i) the utility of concept maps to connect various concepts, ii) aid in problem solving, iii) tool for study and revision, iv) to help in recall of the concepts and v) to memorize the concepts. The reliability estimate for the questionnaire based on the Cronbach Alpha method is 0.87, which is consistent with reliability estimates of perceptions questionnaires from other such studies which obtained reliability estimates from 0.5 to 0.9 (Glenn et. al. 2004). Most of the students were in favour for the use of the concept maps in the classroom. Nearly 70 % students were in the favour of the use of concept mapping in problem solving, 88 % students were of the opinion that concept mapping is useful for study and revision and 80 % students said that concept maps help them to connect various concepts.

6. Discussion

The result of present study suggests that students exposed to the use of concept mapping strategy more effectively improved the student's performance in problem solving than the traditional teaching method. The result of this study shows that students exposed to the use of concept mapping technique while studying IICE significantly higher in well structured problem solving than those students to traditional teaching method. It is in line with the findings of Braselton & Decker (1994), Nnamdi S. Okoye and Okechukwu, R. (2006). Using concept mapping strategy, performance of the students in well structured problem solving improved. This can be attributed to the fact that concept mapping strategy helps students in structural knowledge on how to solve problems. According to Hong, for well structured problems, the student first activates the schema, searched for a solution and then implemented the solution.

Concept mapping broadens perception with more diverse information and promotes a broader and more complex cognitive structure. (Jonassen, D. H. 1997). For well structured problem solving, concept mapping distributes cognitive load between the problem solving stages (Stoyanov 2001). Concept maps acts as cognitive guide through the stages of problem solving (Stoyanov 2001).

But there is no significant difference in performance of the students on ill structured problem solving. For ill structured problems, the students first searched for and selected information and then developed a justification. Ill structured problems have unclear goals, multiple paths and solutions (Ge & Land 2003; Jonassen 1997). Concept maps provide very little help in solving ill structured problems. This may be due to fact that ill structured problems have no explicit set of rules to solve problems, they have multiple solutions, and multiple paths. Further research is needed on interpretation of concept maps to attempt to understand background of students in relation to problem solving performance. Ill structured problems are characterized by insufficient information, existence of alternative method and conflicting approach and lack of clear cut procedure (Ge & Land 2003).

7. Conclusions

The results of present study showed that the mean score of the post test score in problem solving for the experimental group was higher than that of the control group. The results suggest that the concept mapping strategy improved the students' performance in problem solving than the traditional teaching method. Concept mapping helps in solving well structured problems while it does not improve ill structured problem solving performance.

Concept mapping generates conditions for knowledge representation, knowledge reflection and knowledge changing in problem solving (Stoyanov 2001). In addition, the experimental results should be carefully generalized as more research is needed related to gender difference, different subjects and different learning styles in engineering education.

There are several other subjects in mechanical engineering curriculum which stress the importance of concepts, connections between concepts and hierarchy of concepts. These studies could be extended to other aspects of mechanical engineering education.

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